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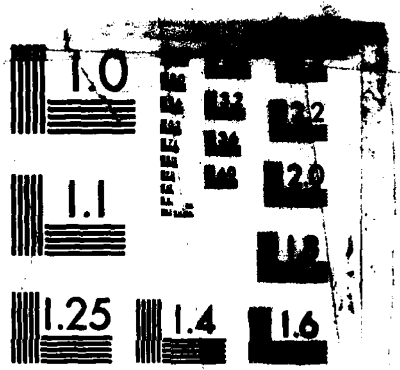

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AD-A158 042

"HOT ELECTRON EMISSION IN SEMICONDUCTORS"

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1st Interim Report
15 November 1984 - 15 January 1985

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"HOT ELECTRON EMISSION IN SEMICONDUCTORS"

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Summary of the Scientific work

The research work on "hot electron emission in semiconductors" was started with the following topics:

a) Electron heating in GaAs/GaAlAs single heterostructures

b) The emission due to the interaction of drifting carriers in GaAs/GaAlAs heterostructures with a periodic grating

c) FIR emission due to streaming of hot carriers in crossed electric and magnetic fields in p-Ge

ad a) The topic of carrier heating in the lateral transport of two-dimensional (2D) systems along semiconductor interfaces and heterojunctions has attracted much interest in the last years, especially due to the applications of these systems for fast field effect transistors[1] and, recently, for hot carrier and real space transfer devices[2]. There are several theoretical papers[3] on the problem of carrier heating in GaAs/AlGaAs heterojunctions.

We have performed FIR emission experiments by passing a lateral current through the 2D electron system of GaAs/AlGaAs single heterojunctions. This heats up the carriers to a carrier temperature T. It has been shown in the experiments of Shah et al.[4] and in femtosecond studies of the intraband relaxation by Erskine et al.[5] that the carriers thermalize very fast to a thermal distribution characterized by the carrier temperature T, via carrier-carrier interaction within less than 100 fs[5]. Since this

is by orders of magnitudes less than the energy relaxation time (10^{-10} to 10^{-9}s) the carrier system itself represents a system in thermal equilibrium.

We have investigated GaAs/AlGaAs heterojunctions with ultrahigh as well as low electron mobility. A relative method of determining the carrier heating in the electric field is introduced, which allows the measurement of T over a wide range of carrier temperatures ($10\,K \leq T \leq 150\,K$) This method uses two narrowband FIR detectors at 35 cm^{-1} (GaAs) and at 100 cm^{-1} (Ge:Ga) for the analysis.

The electron heating is found to increase nearly linearly with the input power and reaches 100 K when the input power exceeds $10^7 eVs^{-1}$ per electron. The values of heating for the three different samples are surprisingly close together although the electron concentration varies by a factor of three and the mobility by a factor of 100. The slopes of the curves are similar which indicates a very general heating law as found in Si-MOSFETs[6].

ad b) Two-dimensional electron systems represent ideal systems for observing optical transitions due to periodically accelerated motion ("Smith-Purcell-effect"[7]): (1) The carriers are confined near the suface and can be brought close to a periodic gate potential; (2) the carrier system is extremely degenerate and high Fermi velocities are present at simultaneously high mobilities giving extremely long mean free paths up to more than 1 μm at the Fermi surface.

We have estimated the emission intensity of a GaAs/AlGaAs heterostructure due to the free-carrier radiation by the motion of the electrons with velocity v near the Fermi surface along a periodic potential with amplitude ΔU and period (a) in a semi-classical model using the dipole radiation theory and Fermi-statistics for the transition probability.

The spectral intensity per frequency interval is for a realistic periodic potential of $\Delta U = 1$ mV in the order of 10^{-10} W/cm^{2}cm^{-1} and should herefore be observable. The intensity is proportional to the square of the periodic potential, and thus may reach values of up to μW/cm^{2}cm^{-1}. The experimental realisation is done by evaporating a semitransparent (NiCr) gate electrode upon a sinusoidal photoresist structure and applying small voltages and a "compensation" voltage along the gate in order to avoid pinch-off effects during the electric field heating of the 2D system. Reproducable results on this new source have not been obtained yet.

ad c) The work on emission due to streaming of hot carriers in p-Ge has been started by the preparation and characterization of the required p-Ge samples. Material with a doping level of $\sim 1 \times 10^{14}$ is used. Samples with the geometry $6 \times 2 \times 1$ mm^3 were polished and contacted on the large surfaces by evaporating In and subsequent annealing at 300°C. Ohmic contacts were achieved and first emission experiments performed. Emission due to the hot hole distribution and a weak cyclotron resonance signal, similar to the results of Komiyama[8] were obtained.

R.A. Höpfel

M. Helm

E. Gornik

Dr. R.A. Höpfel has taken a one year leave of absence to work with AT&T Bell Laboratories, Holmdel, N.J. He will be replaced as associate investigator by Mag. M. Helm. As additional research assistants G. Strasser and J. Smoliner will participate in the project.

References

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The hot electron emission from low and high mobility GaAs/GaAlAs heterostructures was investigated in the FIR range at two frequencies. From the analysis a linear dependence of the electron temperature on input power per electron is found, nearly independent of the sample properties.

The interaction of drifting carriers with periodic gratings in high mobility GaAs/GaAlAs systems is a promising scheme to obtain μW tunable FIR radiation.

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Keywords included

20. No conclusive results have been obtained yet. The realization of streaming motion of hot carriers in p-Ge under crossed electric and magnetic fields is persued at present.

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